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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Snow Accumulation and Disappearance Influenced by Big Sagebrush

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The eradication of sagebrush on western grazing lands to increase forage produced by more palatable understory vegetation may also affect water yields from these lands.

Many of these grazing lands lie at elevations where a large portion of the annual precipitation occurs as snow. This snow is often redeposited in the lee of topographic and vegetative barriers by wind. Where sagebrush is the dominant overstory plant in these vegetative barriers, its eradication could affect snow accumulation and change the hydrology of these high-elevation grazing lands.

Studies are now underway to determine the effects of sagebrush eradication upon snow-accumulation patterns and water yields. To aid in evaluating these studies, more detailed studies of various hydrologic processes on these lands are being made. During the winter and spring of 1963, the influence of natural grassland and big sagebrush upon snow accumulation, snowpack profile characteristics, and snow disappearance was compared as a part of this program of work.

Past Work

Little work has been done in determining relationships between brush cover types and snow in the past. Connaughton,[2] in Idaho, found that snow accumulations in sagebrush were only slightly different from those on a denuded timber area.

Sonder and Alley[3] report that sagebrush control had no effect upon the snow-holding capacity in the Red Desert area in south-central Wyoming, where drifting of snow usually occurs. In the Big Horn Mountains, chemically controlled sagebrush areas appeared to retain snow longer than untreated areas.

Methods of Study

This study was conducted near Dubois, Wyoming, on sagebrush-covered rangeland on the southern flank of the Absaroka Mountain Range. The elevation of the study area is

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[2]*Connaughton, C. A. The accumulation and rate of melting of snow as influenced by vegetation. Jour. Forestry 33: 564-569. 1935.*

[3]*Sonder, Leslie W. and Alley, Harold P. Soil-moisture retention and snow-holding capacity as affected by the chemical control of big sagebrush (Artemisia tridentata Nutt.). Weeds 9(1): 27-35. 1961.*

about 9,500 feet. Big sagebrush (Artemisia tridentata Nutt.) is the predominant species of sagebrush.

To determine how the big sagebrush canopy influences retention and disappearance of snow, these and related factors were measured on comparable natural sagebrush-covered and grass-covered plots. Sagebrush plots had a canopy cover density of about 50 percent.

These plots were 0.1 acre in area (1 chain square), and were situated on level ground within a broad stream-bottom site. Level sites were chosen to minimize snow trapping due to topographic configuration. Two replications of measurements were made. The plots in each replication were located 1 chain apart. The two replications were about 1-1/2 chains apart.

Measurements were made at monthly intervals throughout the winter. During the spring snowmelt period, the intensity was increased to two sampling dates per month. Data were compared by the analysis of variance technique.

A specially devised cylindrical sampler with a cross-sectional area of 3 square feet was used to obtain a measurement of snowpack water equivalent. This was done by converting the weight of snow contained in the sampler to inches of water. The average of five measurements per plot was taken as the amount of snow water accumulated on the plot.

This sampler was used to insure that representative measurements of the snowpack were obtained in the sagebrush cover type, where the snow-sagebrush crown intermixture made it difficult to obtain good samples with a Mount Rose snow tube. For purposes of comparison, this cylindrical sampler was used in both grass and sagebrush cover.

Snowpack profile characteristics were determined by excavating a trench on each plot on each sampling date. The characteristics of the profile were recorded by mapping and photographing. The densities of the strata within the profile were determined by means of a small density core sampler similar to SIPRE standard snow tube.[4]

The type and depth of soil frost was also determined on each plot. Distinction was made only between concrete and nonconcrete frost types. Frost depths were recorded in inches to a depth of 1 foot.

The rates of snowmelt were determined from periodic Mount Rose snow-tube measurements during a portion of the snowmelt period.

Snow Accumulation and Disappearance

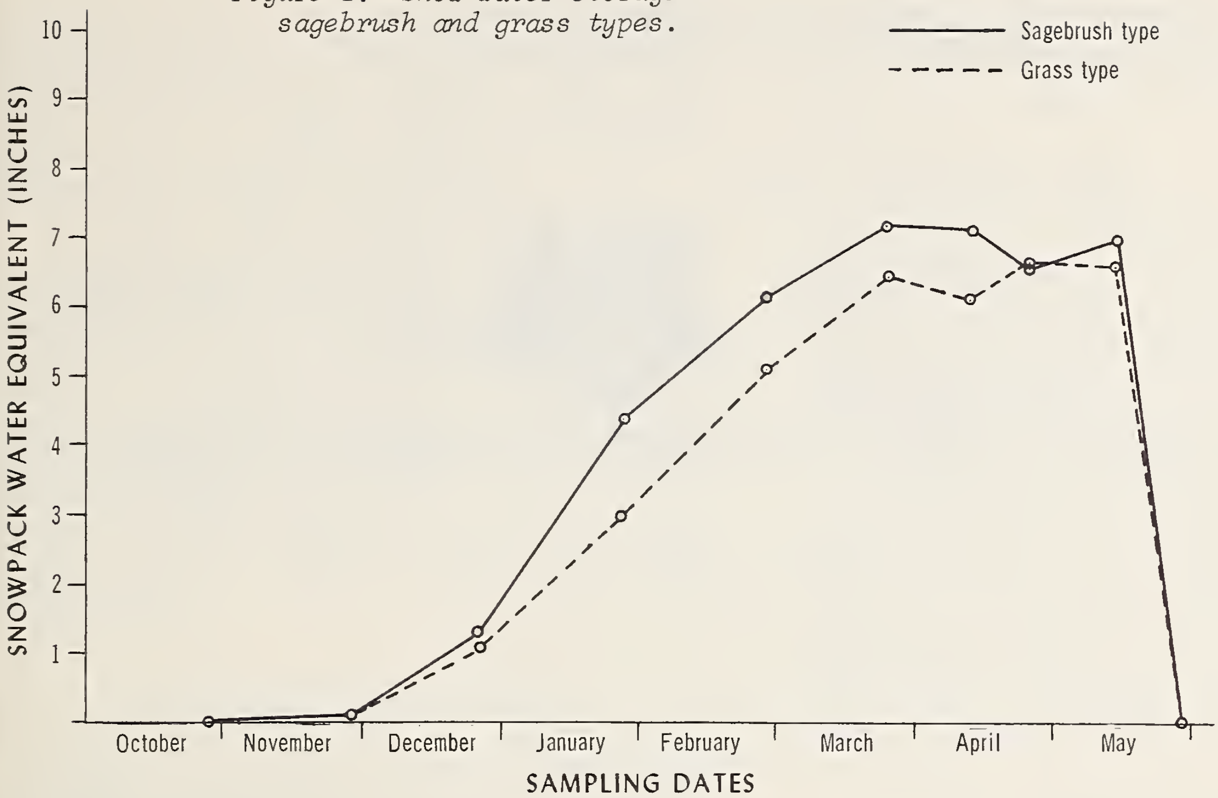
Figure 1 shows the amounts of snow water accumulated on each sampling date. During January, the increase of snow water was greater in sagebrush than in grass. The sagebrush crowns were still exposed during this time.

In February, the crowns became completely covered and the rate of increase of water content became similar in both cover types. The sagebrush-covered plots continued to have greater water content through February and March, as a result of the initial greater efficiency of sagebrush crowns in inducing snow deposition. The differences in accumulated water on February and March sampling dates are significant at the 95 percent level of confidence.

After the March sampling date, snowmelt began and water losses were noted in both cover types. The metamorphism and subsequent melt of snow began earlier and proceeded at greater rates in and adjacent to sagebrush crowns. This is reflected in greater water losses from the sagebrush plots during the first month of melt. The unique radiative properties of snow are responsible for this difference.

[4] *Bader, Henri. The physics and mechanics of snow as a material. 79 pp. In Part II, Sect. B, Cold Regions Sci. and Engin. Phys. Sci. edited by F. J. Sanger. U. S. Army Materiel Command, Cold Regions Res. and Engin. Lab., Corps Engin., Hanover, N. H. 1962.*

Figure 1.--Snow-water storage in sagebrush and grass types.



Solar (short-wave) radiation penetrates into a snowpack, but little is absorbed because of snow's high albedo for this type of radiation. Some of the incident radiation penetrates the snowpack, however, and intercepts sagebrush plant parts. The lower albedo of these materials allows absorption of the radiation, which results in a warming of the plant parts. Heat is then lost to snow by conductance or through long-wave radiation from the plants. For long-wave radiation, snow is nearly a perfect black body; that is, snow has great powers of absorption for long-wave radiant energy, and thus absorbs much of this energy form. The result of these two processes is a warming of the snow, which causes faster metamorphism and melt.

A characteristic melt pattern developed on the sagebrush plots as a result of the above processes. Depressions formed around individual sagebrush plants, while the snowpack between plants remained relatively unchanged. A hummock and depression topography resulted (fig. 2). Little melt occurred in the snowpack over grass during this time, and a

Figure 2.--Voids developing around sagebrush crowns. When these voids reach maximum development, a hummock and depression snow topography results.

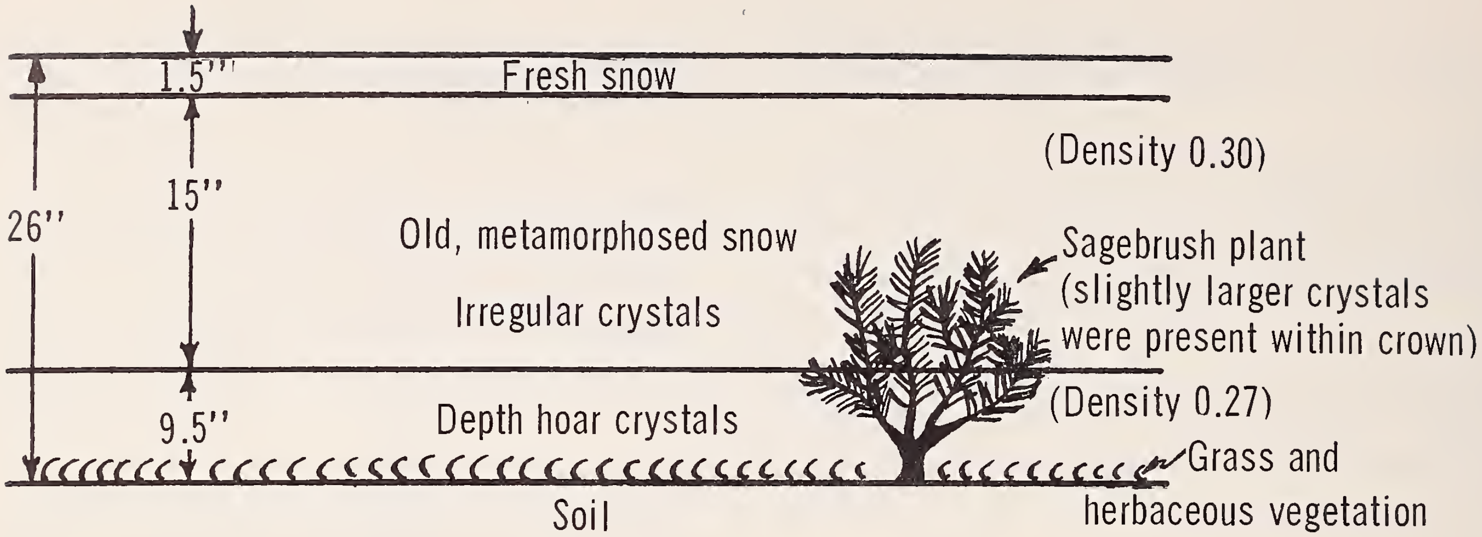


Figure 3.--Snowpack profile in sagebrush cover type (Feb. 26).

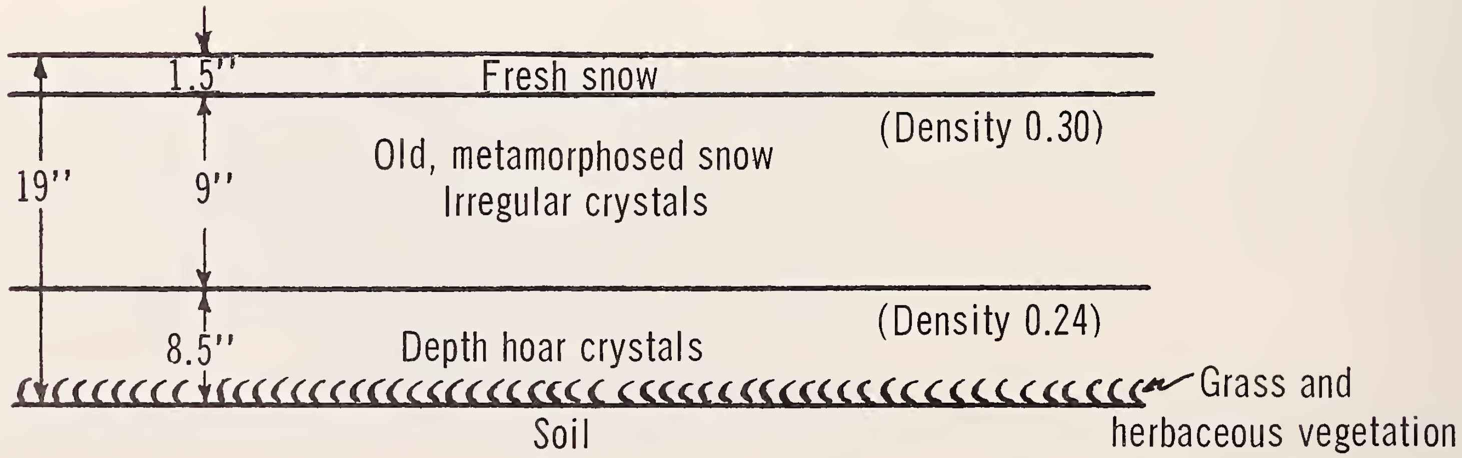


Figure 4.--Snowpack profile in grass cover type (Feb. 26).

net gain in water content was measured. With frequent spring snowfalls, there is a tendency for these depressions around sagebrush plants to fill with new snow. This may explain the slight rise in water content on sagebrush plots during the first half of May.

From May 6 to May 14, frequent Mount Rose snow tube samples were taken to determine the rates of snowmelt over the two cover types. The average rates of decrease were nearly the same in both types (0.38 inch per day in grass and 0.45 inch per day in sagebrush). The grass plots were completely free of snow by May 28, but some snow still persisted between sagebrush plants on the sagebrush plots.

Snowpack Characteristics

Examination of the snowpack profile yielded other information as to the influence of big sagebrush upon snowpack characteristics. Schematic representations of the winter snowpack on the sagebrush- and grass-covered plots (figs. 3, 4), show the only discernible differences in snowpack profile characteristics between cover types to be in the thickness of the various strata of the profile. Differences in the densities of the snow within these strata were slight throughout the winter (table 1).

The layer of depth hoar (figs 3, 4) was first observed in December, and persisted until the snow melted in the spring. The thickness of the layer decreased steadily throughout the course of the study, while the individual crystals grew larger with age.

The layer of old, metamorphosed snow increased in thickness throughout the winter as fresh snow aged and became incorporated into this strata. Throughout the winter, snow crystals in this layer found in and around sagebrush crowns were somewhat larger than those found elsewhere. The boundaries between the strata shown were sharply defined.

In both cover types, numerous small and discontinuous ice lenses were observed within the metamorphosed snow in March. Since these lenses were discontinuous and small, they appear to be of little hydrologic significance.

Table 1.--Densities of snow in strata of snow profile throughout period of study, winter and spring 1963

Date	Density of strata of snowpack by cover type							
	Grass				Sagebrush			
	Hoar above soil	Old snow	Hoar at surface	Fresh snow	Hoar above soil	Old snow	Hoar near surface	Fresh snow
January 29	0.27	0.23	(1)	(1)	0.26	0.21	(1)	(1)
February 26	.24	.30	(1)	(1)	.27	.30	(1)	(1)
March 26	.26	.33	(1)	(1)	.28	.35	(1)	(1)
April 10	.27	.34	0.28	0.22	.27	.32	0.29	0.24
April 25	.31	.34	.28	.23	.30	.34	.36	.24
May 14	.42	.44	(2)	.44	.38	.46	(2)	.39

[1] Not present.
[2] Strata had metamorphosed into old snow since preceding sampling date.

Figure 5.--Sagebrush-covered plot: snowpack as of April 25, 1963.

In April, an important difference in the snowpacks between cover types was observed (figs. 5, 6). A continuous, thin ice sheet had developed in grass plots at the boundary between the depth hoar and metamorphosed snow above. In sagebrush, this feature was non-

Figure 6.--Grass-covered plot: snowpack as of April 25, 1963.

existent; there was instead a gradual transition from depth hoar to metamorphosed snow. Voids were then beginning to form around the sagebrush crowns, and by mid-May these features were well developed.

Frost Observations

There was no evidence of concrete-type frost at any time during the study:

	Average frost depths	
	Grass	Sagebrush
	(Inches)	
October 30	None	None
November 28	4	3.5
December 28	7	7
January 29	12+	12+
February 26	12+	12+
March 26	3	None
April 10	None	None
April 25	None	None
May 14	None	None
May 28	None	None

During the snowmelt period, a continuous sheet of ice from 1 to 2 inches thick was observed overlying the soil surface on grass plots. The soil beneath was mellow, although the moisture contained was frozen. At the same time (mid-May), small patches of ice were observed in small soil depressions in the sagebrush-covered areas. At no time did ice under sagebrush approach a continuous sheet.

The hydrologic importance of the continuous ice sheets over soil in the grass-covered areas could be considerable. Since these sheets are impermeable, melt water may not enter the soil beneath, but may run off over the ice as surface flow. This type of flow would be faster than subsurface flow through saturated soils and, thus, the melt water could reach the stream channels more quickly. Earlier peak flows and incomplete soil moisture recharge could result. Continuous ice sheets within the snowpack could lead to similar results.

Since ice sheets were only observed on grass-covered plots, and since less snow accumulates on grass cover, the conversion of sagebrush areas to grass may understandably have profound effects upon the hydrology of these high-elevation grazing lands. Further study is needed to evaluate the effects of these features upon runoff, streamflow, and soil moisture on larger areas.

Conclusions

1. In areas where induced snow accumulation by topographic configuration is negligible, significantly more snow accumulates in sagebrush-covered areas than in comparable grass-covered areas because of the efficiency of sagebrush crowns in inducing deposition of drifting snow.

2. Continuous layers of ice observed during a considerable portion of the snowmelt period over soil and within the snowpack on grass-covered areas may change the hydrology of high-elevation grazing lands when sagebrush is eradicated.

3. The hydrologic importance of the characteristic melt pattern in sagebrush should be further investigated. The trapping of snow in the depressions after spring snow falls may be important in terms of water yields.

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